Tool-X®

Tech Data Sheet 115
CNC Boring
Oil-based MWF
Nickel Alloy

What is Tool-X? A new line of metalworking fluids that contain a new additive – trillions of carbon-based nano-onions in solution. These nano-onions improve the lubrication along the cutting edge, preventing build-ups and improving heat transfer. The result is longer-lasting tools that cut truer, with more precision, with less force required, than with conventional metal working fluids.

Tool-X improves machining processes. The role of metalworking fluids is to permit tools to change the shape of materials as efficiently and effectively as possible. To achieve this objective, metalworking fluids must counteract common failure modes by reducing heat, adhesion, pressure and wear while providing lubricity under the extreme temperatures and pressures associated with metalworking. Tool-X nanofluid technology enables our metalworking fluids to attain new levels of performance.

Tool-X Benefits: With Tool-X, surface finish is improved (lower Ra, fewer and smaller distortions). Feeds and speeds can be increased, often by 25% or more. Tool life is extended. Problems caused by excess heat (white film layers, long chip sizes, metallurgical damage) can be avoided. Reworks, tool sharpenings, and deburring steps can be reduced or eliminated.

With Tool-X, it's all about the numbers. Tool-X metalworking fluids cost more than conventional fluids, as much as twice as much. But the savings that are possible, through extended tool life, increased productivity, and parts with better surface finish and better dimensional accuracy, can provide users with substantial returns on investment. Let us demonstrate how Tool-X can improve productivity and reduce expenses in your facility.

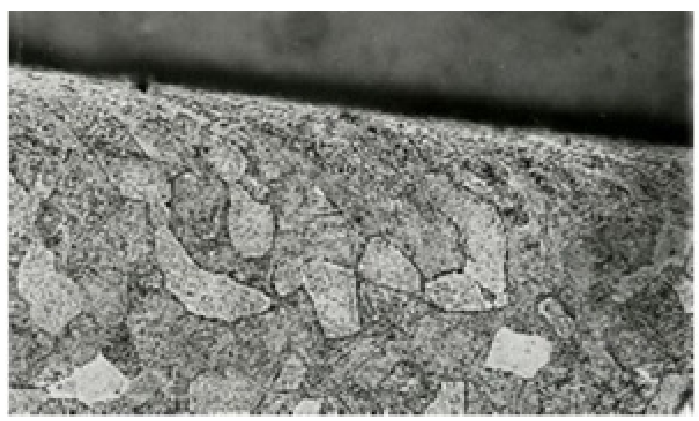
See www.tool-x.net for more information.

Customer: A major aerospace manufacturer

Problem: This customer was interested in testing technology with the potential to extend tool life when machining nickel or titanium super alloys without sacrificing metallurgical quality. Tool life in holes machined in sensitive aerospace alloys is based solely on control of metallurgical damage and not conventional tool wear analysis.

As shown in Figure 1, cutting can result in damage below the surface. The metal grain structure is distorted and near the surface grains are disrupted by melting and recrystallization processes. If the cutting edge does not shear cleanly, the crystalline structure can be dragged or plowed causing distortions. These distortions work harden the surface, which both increases the surface hardness, but also causes embrittlement of the metal, which can lead to microcracks, corrosion and ultimately fatigue and failure.

Figure 1



Another source of metallurgical damage is the formation of white film layers, thought to be the result of excess heat. White film layers have been shown to cause microcracks in rotary parts through a corrosion mechanism.

Testing was proposed to mimic production processes of drilling and boring into high strength high temperature nickel alloy, and to assess the impact of Tool-X on tool life (by assessing metallurgical damage to the test specimen).

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Evaluation Process:

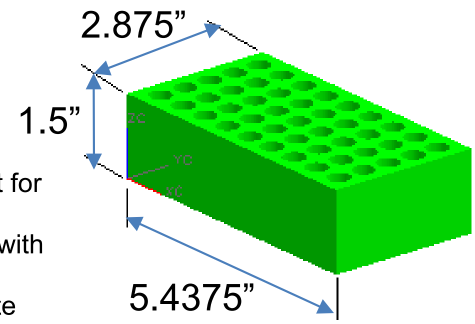
Testing was conducted at the Connecticut Center for Advanced Technology (CCAT). A workpiece of nickel super alloy was provided by the manufacturer – a block in the dimensions shown in Figure 2. Testing was conducted on a Haas Mini Mill using a precision four fluted boring tool developed by Jet Tool & Cutter of Southington, Connecticut, that has been proven to achieve high tool life and exacting dimensional control in both titanium and nickel parts – to within 0.002” loss in size.

The drilling and boring was conducted using first the base oil, TRIM OM300 cutting oil, and then repeated after replacing the oil with the same TRIM OM300 cutting oil with the Tool-X nano-onion additive package blended in.

The test procedure:

- A total of 45 holes were drilled in each workpiece in a 9 x 5 grid using a 0.3230” drill.
- 5 rows (45 holes) were then bored with 0.330 four flute end mill bores.
- Four rows (36 of the 45) of the bored holes were then re-bored using a larger 0.3430” four flute end mill bore.
- Finally three rows (27 of 45) of the previously bored holes was re-bored again using a larger 0.3530” four flute end mill bore.

Figure 2.



The first row, which had only been bored once, at 0.330” in diameter, was sent out for lab evaluation and metallurgical testing. Testing was conducted at an outside metallurgical laboratory, which involved cutting the block and observing the holes with electron microscopes at different locations longitudinally and transversely. Measurements were taken and observations made to assess the presence of white layer films, their prevalence and depth, as well as observing the occurrence of “severe distortions” and or “slight distortions” measured at depths of 0.001” or greater. Their prevalence was recorded from isolated to occasional to intermediate to predominate to continual.

The test methodology was chosen in the expectation that differences in tool life would be observed as distortions after 15 of the 45 holes. In actuality, the tools (drills and bores) held up well through the test, with both fluids performing better than anticipated.

Results:

Figure 3.

CCAT TESTING CNC BORING	Slight Distortion		Severe Distortion	Trace White Layer	Locally Heavy White Layer
Total Exceptions	Neg	Pos	Neg	Neg	Neg
OM 300 Oil Only (L)	0	4	2	0	0
OM 300 Oil Only (T)	3	0	3	4	4
OM 300 Oil w Tool-X (L)	0	8	0	0	0
OM 300 Oil w Tool-X (T)	0	8	0	0	0

The test results summarized in Figure 3 show that Tool-X, when added to cutting oil, significantly improved the quality of the sub-surface metallurgy of the nine bored holes. Tool-X eliminated any observations of white layer in the nine holes, eliminated severe distortions, and reduced the average “slight distortion” measured to 0.001” in eight out of nine bored holes. The slight distortions were either predominate or continual, but shallow in all nine holes, which were easily within the desired specifications.

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Metallurgical observations of the same cutting oil without the added Tool-X found either traces or locally heavily white layers in six of the nine holes, severe distortions in four holes, and significant “slight distortions” (depths of 0.004” to 0.008”) in three holes. Only four of the nine bored holes using the base oil were within desired tolerances.

Detailed results can be found in Figure 4.

The addition of Tool-X nano-onions to a good base line cutting oil was shown to improve the cutting performance. The mechanisms, while not fully understood, are believed to include:

- Improved lubricity / reduced friction between tool, part, and chip
- Reduced adhesion / microwelding of debris to the cutting edge (reduced built up edge)
- Cleaner shearing, less plowing or dragging at the cutting edge of the tool.
- Cooler temperatures on part, chip, and tool away from the cutting edge, preventing white film formation, recrystallization, and built up edge on flank surfaces.

Further study is needed to assess the mechanisms by inspecting tool surfaces under electron microscopy, and to test Tool-X with PVD and CBN tools when used on nickel and titanium super alloys.

Conclusion:

The addition of Tool-X nano-onions to TRIM OM300 base cutting oil demonstrated significant improvement to the sub-surface metallurgy of nine holes bored into a high temperature high strength aerospace nickel alloy block. Severe distortions and white layers were eliminated and each part was within the manufacturer's stated tolerance, while only three of nine holes met that same standard using the base OM300 cutting oil. Tool life appears to be extended to at least 45 holes, based on the limited sample size inspected, from an expected 15 to 20 holes.

Figure 4

	Location 5	Location 10	Location 15	Location 20	Location 25	Location 30	Location 35	Location 40	Location 45	Total Exceptions Neg	Pos
Slight Distortion											
OM 300 Oil Only (L)	.0001 Pred	.0001 Cont	.0002 Cont	.0002 Pred	.0001 Cont	.0001 Cont	.0002 Cont	.0002 Cont	.0002 Cont	0	4
OM 300 Oil Only (T)	.0004 Int	.0002 Int	.0002 Pred	.0002 Pred	.0004 Pred	.0008 Pred	.0002 Pred	.0002 Pred	.0002 Pred	3	0
OM 300 Oil w Tool-X (L)	.0002 Cont	.0001 Pred	.0001 Pred	.0001 Pred	.0001 Pred	.0001 Cont	.0001 Cont	.0001 Cont	.0001 Cont	0	8
OM 300 Oil w Tool-X (T)	.0002 Cont	.0001 Pred	.0001 Pred	.0001 Int	.0001 Int	.0001 Cont	.0001 Cont	.0001 Cont	.0001 Int	0	8
Severe Distortion											
OM 300 Oil Only (L)	None	None	None	None	.0001 Occ	None	.0001 Occ	None	None	2	N/A
OM 300 Oil Only (T)	None	.0001 Occ	None	None	.0001 Int	.0003 Int	None	None	None	3	N/A
OM 300 Oil w Tool-X (L)	None	None	None	None	None	None	None	None	None	0	N/A
OM 300 Oil w Tool-X (T)	None	None	None	None	None	None	None	None	None	0	N/A
Trace White Layer											
OM 300 Oil Only (L)	None	None	None	None	None	None	None	None	None	0	N/A
OM 300 Oil Only (T)	None	.000005 Iso	None	None	None	.00005 Int	None	.00005 Int	.00005 Int	4	N/A
OM 300 Oil w Tool-X (L)	None	None	None	None	None	None	None	None	None	0	N/A
OM 300 Oil w Tool-X (T)	None	None	None	None	None	None	None	None	None	0	N/A
Locally Heavy White Layer											
OM 300 Oil Only (L)	None	None	None	None	None	None	None	None	None	0	N/A
OM 300 Oil Only (T)	.0003 Occ	.0006 Iso	None	None	None	.0001 Occ	None	.0001 Occ	None	4	N/A
OM 300 Oil w Tool-X (L)	None	None	None	None	None	None	None	None	None	0	N/A
OM 300 Oil w Tool-X (T)	None	None	None	None	None	None	None	None	None	0	N/A